Evaluation of Physical Processes in the GFSv16 PBL

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Introduction

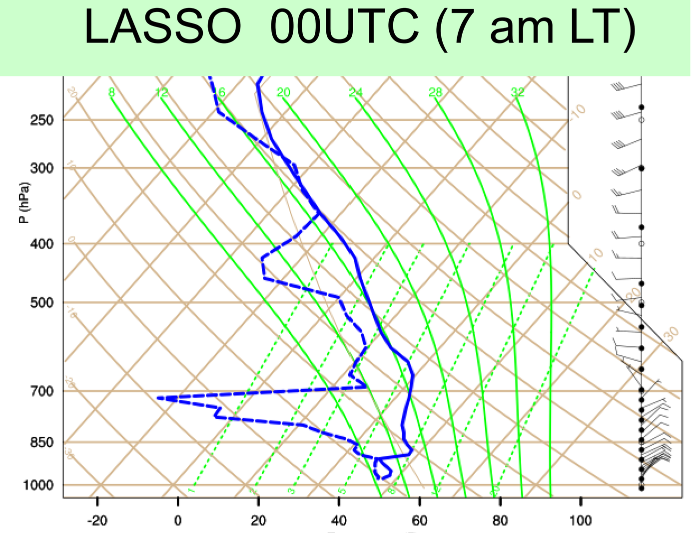
Parameterization of the planetary boundary layer (PBL) aims to accurately represent both small-scale (local) turbulent mixing as well as the larger-scale, convectively driven (nonlocal) mixing that can take place in an unstable atmosphere and the entrainment processes that occur at the PBL top. Multiple methods have been proposed to parameterize these effects.

In the current operational version of the Global Forecast System (GFSv16), the local transport by turbulent eddies is represented by an eddy diffusion (ED) scheme based on the prognostic turbulent kinetic energy (TKE). The nonlocal transport is a function of the prognostic updraft and downdraft mass fluxes (MF) within the PBL. The implementation of this TKE-EDMF scheme was one of the primary changes in the upgrade from v15 to v16. The v15 PBL parameterization used eddy diffusion coefficients computed from the PBL depth, stability, and wind profile. The EDMF approach was used for strongly unstable regimes, but for weakly unstable PBLs, a countergradient method was used in v15 *(Han and Bretherton, 2019)*.

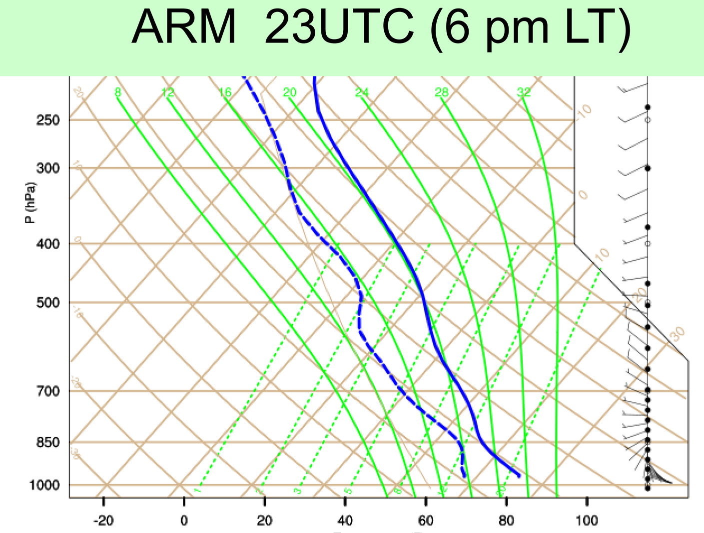
In this presentation we compare results from the Common Community Physics Package (CCPP) Single Column Model (SCMv5.0) simulations using these two PBL parameterizations, to illustrate and better understand the impact of this change.

Two cases from the SCM's preprocessed cases were used. The LASSO 18 May 2016 case is a large eddy simulation of shallow convection. The ARM case is from 26 June 1997 and the first diurnal cycle of this convective case is shown here. Initial conditions are shown in the skewT diagrams below.

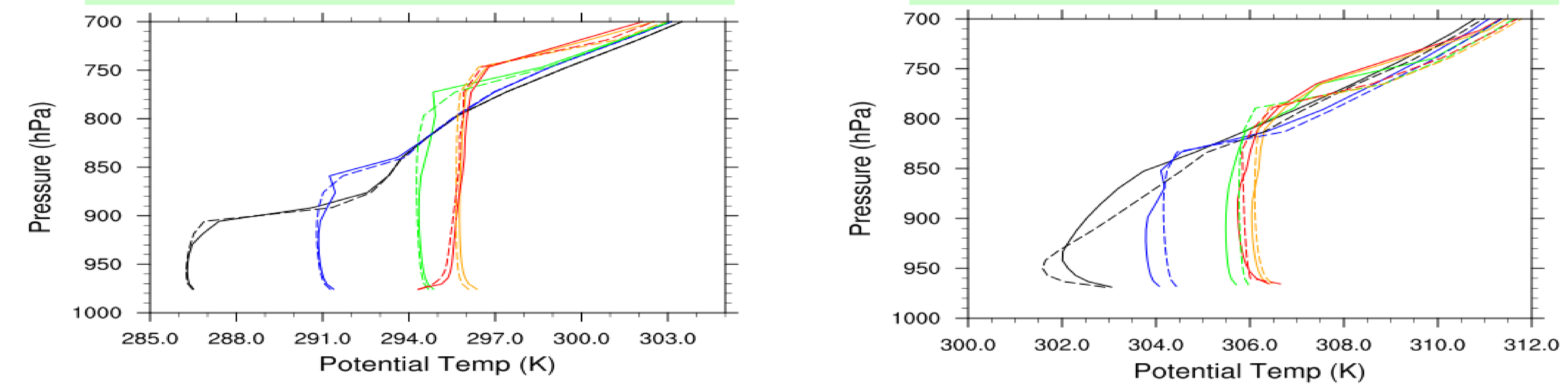
LASSO 00UTC (7 am LT)



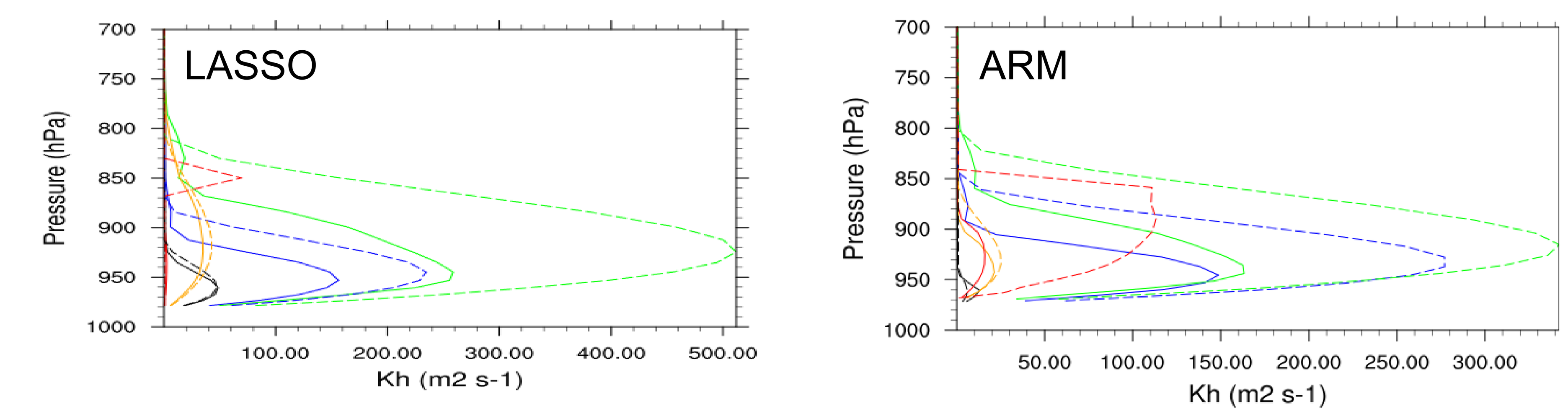
ARM 23UTC (6 pm LT)



LASSO Case ARM Case



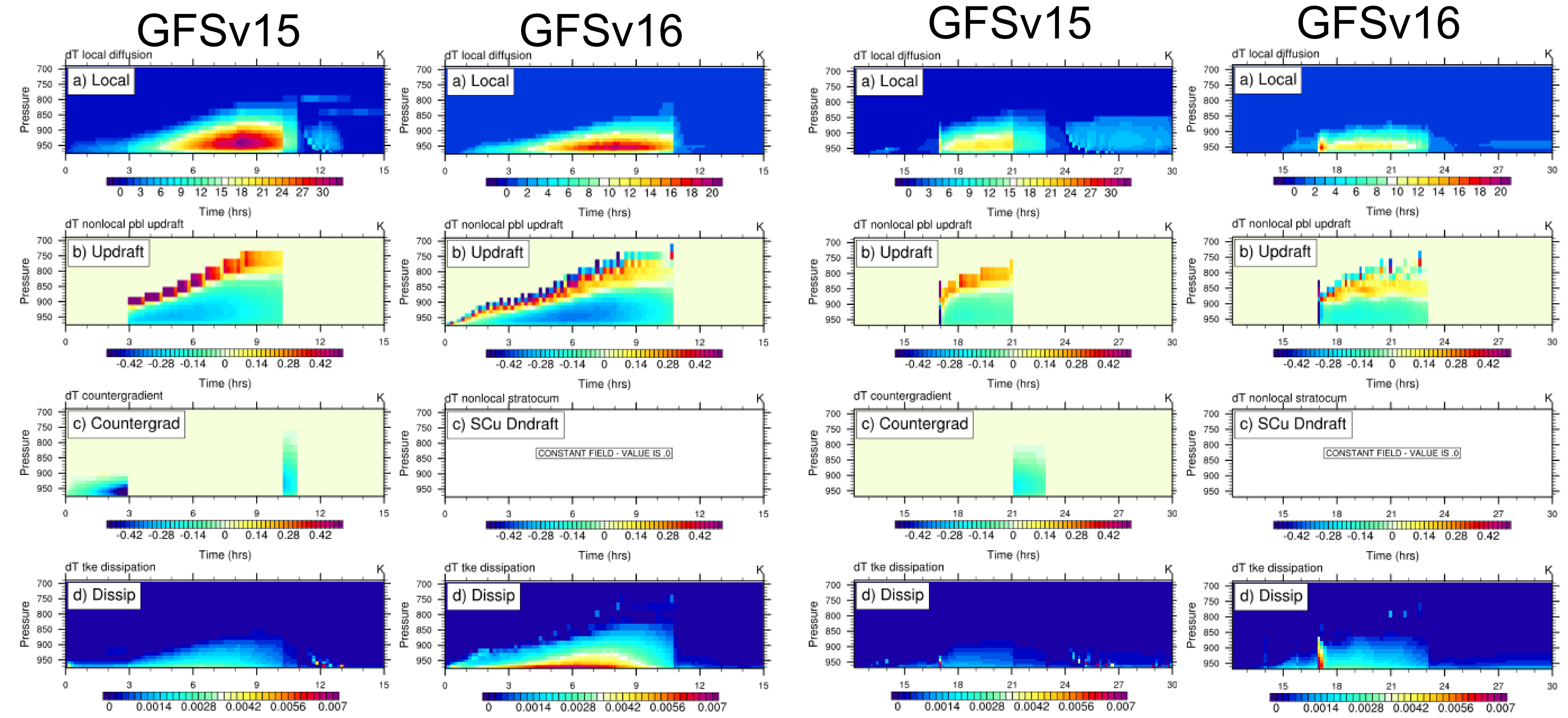
Potential temperature profiles at 9am (black), noon (blue), 3pm (green), 6pm (gold), and 9pm (red) local time (CDT), illustrating the growth of the PBL. Solid lines are from the v16 run, dashed lines are from the v15.



Vertical profiles of the eddy diffusivity coefficient for heat (Kh) for the v16 (solid) and v15 (dashed) schemes. Colors correspond to the times as in the figure above. The TKE-EDMF scheme has smaller values of Kh compared to the v15 scheme.

LASSO case ARM case

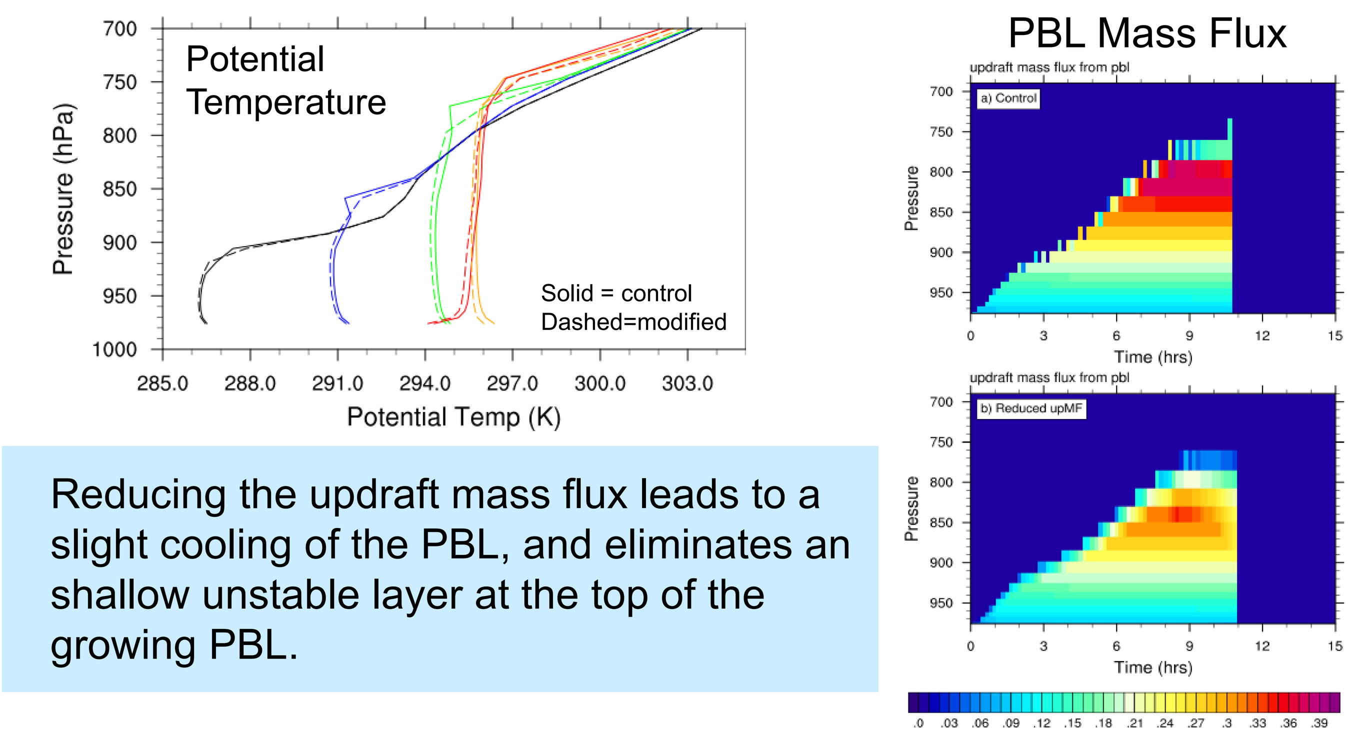
GFSv15 GFSv16 GFSv15 GFSv16



Components of the temperature change due to eddy diffusion. For these experiments, the local term is by far the largest, and has the most impact near the surface. While the PBL depth is nearly identical between the runs, the local term in the v16's TKE-EDMF scheme is smaller in magnitude and shallower. Warming due to buoyant updrafts occurs through a deeper layer in v16, and at lower vertical levels. The updraft term also induces cooling at the top of the PBL in v16, which is not seen in the v15 scheme. The downdraft term is zero, since no stratocumulus clouds are present in these simulations.

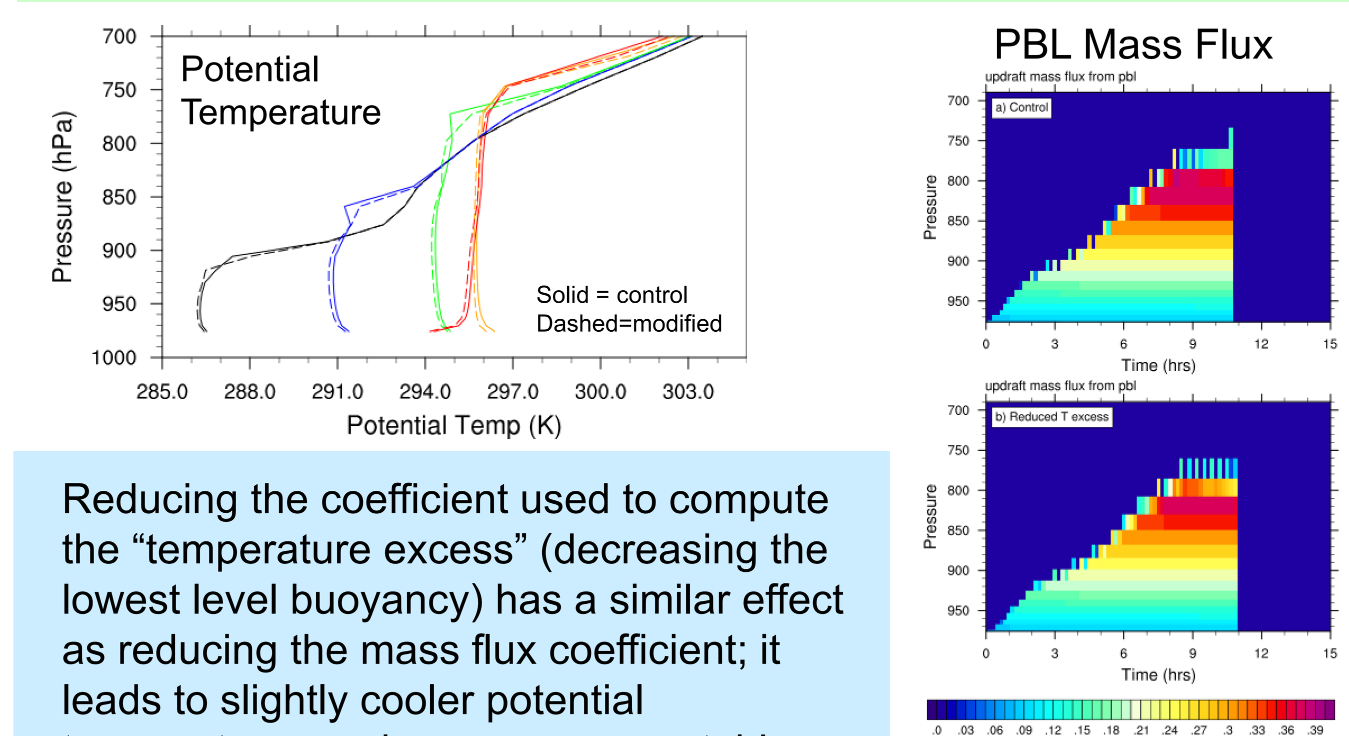
Parameter Variations – LASSO case

1) Reduce the coefficient of mass flux



Reducing the updraft mass flux leads to a slight cooling of the PBL, and eliminates an shallow unstable layer at the top of the growing PBL.

2) Reduce the "temperature excess"



Reducing the coefficient used to compute the "temperature excess" (decreasing the lowest level buoyancy) has a similar effect as reducing the mass flux coefficient; it leads to slightly cooler potential temperatures and removes an unstable layer at the top of the growing PBL.

Discussion

The change in PBL parameterization from the hybrid EDMF scheme in the GFSv15 to the TKE-EDMF scheme in v16 has led to changes in the magnitude and partitioning of the local and nonlocal diffusion terms. It has been reported that the v16 PBL tends to be overmixed, which may be related to the increases in the nonlocal components. Many parameters in the PBL scheme have specified values that are inherently uncertain. The potential impact of varying two of these parameters was shown.

In addition, the CCPP-SCM was shown to be a useful tool for contributing to the understanding of proposed physics modifications.

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